

February 10, 1876.

Dr. J. DALTON HOOKER, C.B., President, in the Chair.

The Right Hon. Lord Aberdare and the Right. Hon. George Selater-Booth were admitted into the Society.

The Right Hon. Benjamin Disraeli, whose Certificate had been suspended, as required by the Statutes, was balloted for and elected a Fellow of the Society.

The Presents received were laid on the table, and thanks ordered for them.

The following Papers were read :—

I. “On Repulsion resulting from Radiation.”—Part III. By WILLIAM CROOKES, F.R.S. &c. Received January 5, 1876.

(Abstract.)

This paper contains an account of experiments on the action of radiation on bodies the surfaces of which have their radiating and absorbing powers modified by various coatings. The difference between a white and a lampblack surface in this respect was at first not very decided; and experiments have been instituted with the object of clearing up some anomalies observed in the actions. Two pith disks, one white and the other black, were suspended on a light arm in a glass bulb by means of a fine silk fibre; after perfect exhaustion the white and black disks were found to be equally repelled by heat of low intensity, such as from the fingers, warm water, &c. A copper ball was then tried at gradually increasing temperatures. Up to 250° C. it repelled both equally, above that the black was more repelled than the white, and at a full red heat the repulsion of the black disk was very energetic. A lighted candle acts with more energy than the red-hot copper.

The presence of even a small quantity of aqueous vapour in the exhausted apparatus almost, if not quite, neutralizes the more energetic action which luminous rays appear to exert on a blackened surface.

After describing several different modifications and some new forms of apparatus devised to facilitate experiment, the author gives a drawing of an instrument which enables him to get quantitative measurements of the amount of incident light falling on it. It consists of a flat bar of pith, half black and half white, suspended horizontally in a bulb by means of a long silk fibre. A small magnet and reflecting-mirror are fastened to the pith, and a controlling magnet is fastened outside so that it can slide up and down the tube, and thus increase or diminish

sensitiveness. The whole is completely exhausted, and then enclosed in a box lined with black velvet, with apertures for the rays of light to pass in and out. A ray of light reflected from the mirror on to a graduated scale, shows the movements of the pith bar. The degrees of deflection produced by the light of a candle at distances from 6 feet to 35 feet are given.

The experimental observations and the numbers which are required by the theoretical diminution of light with the square of the distance are sufficiently close, as the following figures show :—

Candle 6 feet off gives a deflection of 218°			
„ 12	„	„	54
„ 18	„	„	24·5
„ 24	„	„	13
„ 10	„	„	77
„ 20	„	„	19
„ 30	„	„	8·5

The effect of two candles side by side is practically double, and of three candles three times that of one candle.

The action of various solid and liquid screens is next given.

A candle 3 feet off, giving a deflection of 180°, has its action reduced to the following amounts by

Yellow glass	161°
Blue „	102
Green „	101
Red „	128
Water	47
Alum	27

A candle on each side of the apparatus, and equidistant from it, keeps the index ray of light at zero ; by shading off either one or the other the light flies off to either extremity of the scale. This gives a ready means of balancing two sources of light one against the other. Thus, retaining the standard candle 48 inches off on the left of the bar, the index was brought to zero by placing on the right

2 candles	67 inches off,
1 candle behind solution of sulphate of copper . .	6 „
„ „ alum plate	14 „
A small gas-burner	113 „

These experiments show how conveniently and accurately this instrument can be used as a photometer. By balancing a standard candle on one side against any source of light on the other, the value of the latter in terms of a candle is readily shown ; thus in the last experiment the

standard candle 48 inches off was balanced by a gas-flame 113 inches off. The lights were therefore in the proportion of 48^2 to 113^2 , or as 1 to $5\frac{1}{2}$. The gas-burner was therefore equal to $5\frac{1}{2}$ candles.

By interposing screens of water or plates of alum, and so practically cutting off all the dark heat, the actual luminosity is measured. In addition to this, by interposing coloured glasses or solutions, any desired colours can be measured either against the total radiation from a candle, its luminous rays, or any desired colour. One coloured ray can be balanced against another coloured ray, by having differently coloured screens on either side.

The variations in the luminosity of a "standard" candle will cease to be of importance. Any candle may be taken; and if it be placed at such a distance from the apparatus that it will give a uniform deflection, say of 100 divisions, the standard can be reproduced at any subsequent time; and the burning of the candle may be tested during the photometric experiments by taking the deflection it causes from time to time, and altering its distance, if needed, to keep the deflection at 100 divisions.

If the pith bar in this instrument be blacked on alternate halves, an impetus given by a ray of light always acts in the same direction of movement. A candle causes it to spin round very rapidly until the suspending fibre is twisted up, and the rotation is stopped by the accumulated torsion.

By arranging the apparatus so that the black and white surfaces are suspended on a pivot instead of by a silk fibre, the interfering action of torsion is removed, and the instrument will rotate continuously under the influence of radiation. To this instrument the author has given the name of the "Radiometer," or "Light-Mill." It consists of four arms of very fine glass, supported in the centre by a needle-point, and having at the extremities thin disks of pith lampblackened on one side, the black surfaces all facing the same way. The needle stands in a glass cup, and the arms and disks are delicately balanced so as to revolve with the slightest impetus.

In the 'Proceedings of the Royal Society' for 1875 (vol. xxiii. p. 373), the author gave a brief account of some of the earlier experiments with these instruments. In the present paper he enters very fully into the various phenomena presented by them, and gives Tables showing the number of revolutions made by the radiometer when exposed to a constant source of light removed different distances from the instrument. The law is that the rapidity of revolution is inversely as the square of the distance between the light and the instrument.

When exposed to different numbers of candles at the same distance off, the number of revolutions in a given time are in proportion to the number of candles, two candles giving twice the rapidity of one candle, and three giving three times, &c.

The position of the light in the horizontal plane of the instrument is

of no consequence, provided the distance is not altered; thus two candles one foot off give the same number of revolutions per second, whether they are side by side or opposite to each other. From this it follows that if the radiometer is brought into a uniformly lighted space it will continue to revolve. This is proved to be the case by experiment.

The speed with which a sensitive radiometer will revolve in full sunshine is almost incredible. Nothing is apparent but an undefined nebulous ring, which becomes at times almost invisible. The number of revolutions per second cannot be counted, but it must be several hundreds, for one candle will make the arms spin round forty times a second.

The action of dark heat (*i. e.* from boiling water) is to repel each surface equally, and the movement of the radiometer is therefore arrested if a flask of boiling water is brought near it. The same effect is produced by ice.

From some observations made by the author, it appears probable that heat of a still lower refrangibility repels the white more than it does the black surface. Many instances are given of the radiometer revolving the reverse way. Thus breathing gently on the instrument will generally cause this effect to be produced.

An experiment is described with a radiometer the moving parts of which are of aluminium, blacked on one side. When exposed to the radiation from a candle the arms revolve the normal way. On removing the candle they revolve the reverse way. Heated with a Bunsen burner the arms revolve the normal way as they are getting hot; but as soon as the source of heat is removed and cooling commences, rotation sets up in the reverse way, and continues with great energy till the whole is cold. The reverse movement during the cooling is apparently equal in energy to the normal movement as it is being heated.

It is easy to get rotation in a radiometer without having the surfaces of the disks differently coloured. An experiment is described with one having the pith disks blacked on both sides. On bringing a candle near it, and shading the light from one side, rapid rotation is produced, which is at once altered in direction by moving the shade to the other side.

The author describes many forms of radiometer, by means of which the movements can be exhibited to a large audience, or can be made to record themselves telegraphically on a self-recording instrument.

II. "On Repulsion resulting from Radiation."—Part IV. By WILLIAM CROOKES, F.R.S. &c. Received February 5, 1876.

(Abstract.)

In this paper the author describes experiments on the repulsion produced by the different rays of the solar spectrum. The apparatus employed is the horizontal beam suspended by a glass fibre and having